DESIGN OF SMALL HEAT EXCHANGER
(DOUBLE PIPE TYPE)

MOHAMAD SHAFIQ BIN ALIAS

Thesis submitted in fulfillment of the requirements
for the award of the degree of
Bachelor of Mechanical Engineering

Faculty of Mechanical Engineering
UNIVERSITI MALAYSIA PAHANG

DECEMBER 2010

UNIVERSITI MALAYSIA PAHANG
FACULTY OF MECHANICAL ENGINEERING

We certify that the project entitled "Design of Small Heat Exchanger (Double Pipe Type)" is written by Mohamad Shafiq Bin Alias. We have examined the final copy of this project and in our opinion; it is fully adequate in terms of scope and quality for the award of the degree of Bachelor of Engineering. We herewith that it be accepted in partial fulfillment of the requirements for the degree of Bachelor of Mechanical Engineering.

Dr. Agung Sudrajad

Examiner Signature

SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project and in my opinion, this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

Signature :
Name of Supervisor : Dr. Maisara Mohyeldin Gasim Mohamed
Position : Lecturer
Date :

STUDENT'S DECLARATION

I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. This project has not been accepted for any degree and is not concurrently submitted for award of other degree.

Signature
Name: Mohamad Shafiq Bin Alias
ID Number: MA07083
Date:

ACKNOWLEDGEMENTS

I am grateful and would like to express my sincere gratitude to my supervisor Dr. Maisara Mohyeldin Gasim Mohamed for his genius ideas, invaluable guidance, continuous encouragement and constant support in making this research possible. He has always impressed me with his outstanding professional conduct. I appreciate his consistent support from the first day I was start this project to these concluding moments. I am truly grateful for his commitment to this project. I also sincerely thanked him for the time spent proofreading and correcting my many mistakes.

My sincere thanks go to Mr. Mohd Shah bin Pilus who helped me for provided assistance at various occasions at Kg. Geduk Enterprise workshop in many ways throughout the project and his views and tips are useful indeed.

My special thanks to my father, Mr Alias bin Ab Gani and my mother, Mrs Zalha binti Pilus which support me to achieve my goals and given me the strength to continue my studies up to this level. I am also grateful to my my colleagues for their sacrifice, patience, and understanding that make this project was possible.

ABSTRACT

Heat exchanger is one of the important devices in cooling and heating process in factories, buildings, transports and others. The heat exchanger is found in large construction to support cooling process such as fossil fuel power plant. For this research, the small heat exchanger of double pipe type is constructed which wants to make it practicality in daily life such for saving fuel in vehicle. So, in this research, the best design for the small double pipe heat exchanger is choose based on TEMA specification. For this research, the hot air from engine bay is cooling down by using water pipe as the cold water where the temperature inlet and outlet for both fluids are specified. In this research, the properties of materials and its size are considered design process. After choosing the best design, the heat exchanger is fabricated by using sawing, flame-cutting, oxy-acetylene welding and drilling. The experiment is performed under two difference conditions where cold water flow rate is manipulated. From the experiment, the temperature of the hot air is dropped faster when using high flow rate of water with constant flow rate of hot air and the overall heat transfer coefficient is increased when water flow rate is increased.

ABSTRAK

Penukar haba adalah peralatan penting dalam proses penyejukan dan pemanasan di dalam kilang, banguanan, pengangkutan dan lain-lain. Penukar haba dijumpai di dalam pembinaan yang besar untuk menampung proses penyejukan seperti pelantar janakuasa bahan bakar fosil. Untuk kajian ini, penukar haba kecil yang berjenis tiub berkembar dibina dimana mahu membuatkannnya praktikal di dalam kehidupan seharian seperti menjimatkan bahan bakar di dalam kenderaan. Oleh itu, di dalam kajian ini, rekabentuk penukar haba kecil yang berjenis tiub berkembar yang terbaik dipilih berdasarkan spesifikasi TEMA. Untuk kajian ini, udara panas daripada kawasan enjin disejukkan dengan menggunakan air paip sebagai air sejuk dimana suhu keluar dan masuk untuk kedua-dua bendalir ditakrifkan. Di dalam kajian ini, sifat bahan dan saiz adalah diambil kira dalam proses rekabentuk. Selepas memilih rekabentuk yang terbaik, penukar haba difabrikasikan dengan menggunakan gergaji, pemotongan api, kimpalan oksigen-acetylene dan penggerudian. Eksperimen dilakukan di bawah dua keadaan berlainan dimana arus air sejuk dimanipulasikan. Daripada eksperimen, suhu udara panas diturunkan dengan cepat selepas menggunakan arus air yang tinggi dengan arus udara yang tetap.

TABLE OF CONTENTS

		Page
EXAMINER'S DECLARATION		ii
SUPERVISOR'S DECLARATION		iii
STUDENT'S DECLARATION		iv
ACKNOWLEDGEMENTS		v
ABSTRACT		vi
ABSTRAK		vii
TABLE OF CONTENTS		viii
LIST OF TABLES		xi
LIST OF FIGURES		xii
LIST OF SYMBOLS		xv
LIST OF ABBREVIATIONS		xvii
CHAPTER 1	**INTRODUCTION**	
1.1	Introduction	1
1.2	Problem Statement	1
1.3	Objectives	2
1.4	Scope of Research	2
1.5	Significance of Research	2
CHAPTER 2	**LITERATURE REVIEW**	
2.1	Introduction	3
2.2	Definition of Heat Exchanger	3
2.3	Function of Heat Exchanger	4
2.4	Where Can Find Heat Exchanger	4
	2.4.1 Vehicle	4
	2.4.2 Laboratory	6
	2.4.3 House	6
	2.4.4 Industry	8

2.3	Criteria For Heat Exchanger Selection	10
2.4	Flow Arrangements of Heat Exchanger	10
2.5	Fluid Fundamentals In Heat Exchanger	11
2.6	Type of Heat Exchanger	12
	2.6.1 Double Pipe Heat Exchanger	12
	2.6.2 Shell and Tube Heat Exchanger	13
	2.6.3 Compact Heat Exchanger	15
	2.6.4 Flate Plate Heat Exchanger	17
2.7	Construction of Double Pipe Heat Exchanger	17
2.8	Overall Heat Transfer Coefficient of Double Pipe Heat Exchanger	18
2.9	Log Mean Temperature Difference (LMTD) Method For Double Pipe Heat Exchanger	20
2.10	Effectiveness-NTU Method for Double Pipe Heat Exchanger	21

CHAPTER 3 SIMULATION

3.1	Introduction	24
3.2	Flow of Project	25
3.3	Heat Exchanger Calculator	26
3.4	Specified Temperature and Flow Rate of Heat Exchanger	29
3.5	Choose the Material for Heat Exchanger	30
3.6	Simulated Heat Exchanger Design with Microsoft Visual basic 6.0	31
3.7	Choose the Design	32
3.8	The Heat Exchanger Design Based on TEMA Specification	32

CHAPTER 4 FABRICATION

4.1	Introduction	36
4.2	Sawing the Tube Metal	36
4.3	Flame-Cutting the Plate Metal	38
4.4	Oxy-Acetylene Welding	38
4.5	Drilling Sheet Metal	39
4.6	Shell Part	40
4.7	Rear End head Part	42

4.8	Front End Stationary Head	43
4.9	Assembly the Parts	44
4.10	Air/Water Test for Heat Exchanger	45

CHAPTER 5 RESULTS AND DISCUSSION

5.1	Introduction	46
5.2	Experiment of Heat Exchanger	46
5.3	Experiment Result	47
5.4	Experiment Analysis	49

CHAPTER 6 CONCLUSION AND RECOMMENDATIONS

5.1	Conclusions	55
5.2	Recommendations	55

REFERENCES		56
APPENDICES		57
A	Gantt Chart PSM 1	57
B	Gantt Chart PSM 2	58
C	Properties of Solid Metal	59
D	Properties of Solid Non-metal	62
E	Properties of Saturated Water	63
F	Properties of Air at 1 atm Pressure	64
G	TEMA Specification for Tubular Heat Exchanger	65
H	Solidwork Drawing of Double Pipe Heat Exchanger	66

LIST OF TABLES

Table No.	Title	Page
3.1	Design of heat exchanger	32
5.1	Flow rate and temperature reading (1)	48
5.2	Flow rate and temperature reading (2)	49
5.3	Analysis of heat exchanger (1)	51
5.4	Analysis of heat exchanger (2)	52
5.5	Result of the overall transfer coefficient	54

LIST OF FIGURES

Figure No.	Title	Page
2.1	Radiator	5
2.2	Turbocharger engine	5
2.3	Condenser	6
2.4	Water heater	7
2.5	Water heater system	8
2.6	Superheater	9
2.7	Superheater system	9
2.8	Multipass crossflow arrangement	11
2.9	Double tube heat exchanger (parallel flow)	13
2.10	Double tube heat exchanger (counter flow)	13
2.11	One-shell passes and two-tubes pass heat exchanger	14
2.12	Two-shells pass and two-tubes pass heat exchanger	14
2.13	Spiral tube heat exchanger	15
2.14	Compact heat exchanger (unmixed)	16
2.15	Compact heat exchanger (mixed)	16
2.16	Flat plate heat exchanger	17
2.17	Hairpin heat exchanger	18
2.18	Heat transfer of double pipe heat exchanger	19
3.1	Project Flow	25
3.2	Double pipe heat exchanger (counter-flow)	26
3.3	Heat Exchanger Double Pipe Calculator 1	28
3.4	Heat Exchanger Double Pipe Calculator 2	29

3.5	Car engine bay	30
3.6	Double tube heat exchanger	31
3.7	Hairpin heat exchanger	33
3.8	Shell Type	34
3.9	Front End Stationary Head Type	35
3.10	Rear End Head Type	35
3.11	Heat exchanger drawing	35
4.1	Hacksaw	37
4.2	Power Hacksaw	38
4.3	Flame cutting equipment	39
4.4	Oxy-acetylene welding	39
4.5	The Bench Drilling Machine	39
4.6	Shell (TEMA)	40
4.7	Sawing on stainless steel pipe	40
4.8	Flame cutting result	41
4.9	Welding on steel plate and stainless steel pipe	41
4.10	Welding on stainless steel pipe and small steel pipe	42
4.11	Rear end head (TEMA)	42
4.12	Rear end head part	43
4.13	Front End Stationary Head	43
4.14	Rear end head welding	44
4.15	Heat exchanger assembly	44
4.16	Heat exchanger air/water test	45
5.1	Apparatus configuration	47

5.2	Graph heat transfer rate versus Log Mean Temperature Difference (1)	53
5.3	Graph heat transfer rate versus Log Mean Temperature Difference (2)	53

LIST OF SYMBOLS

A	Area
A_s	Surface area
A	Cross section area
A_i	Area of the inner surface of the wall
A_o	Area of the outer surface of the wall
A_s	Area of surface
C_{pc}	Specific heat of cold fluid
$\dot{C}_{ph}$	Specific heat of hot fluid
C_h	Heat capacity rate of hot fluid
C_c	Heat capacity rate of cold fluid
$C_{\min}$	Minimum heat capacity rate
c	Capacity ratio
D	Diameter of tube
D_i	Inner diameter of tube
D_o	Outer diameter of tube
ε	Effectiveness
h_i	Inner fluid convection coefficient
h_o	Outer fluid convection coefficient
L	Length of tube
ṁ	Mass flow rate
m	Graph gradient

m_c	Mass flow rate of cold fluid
m_h	Mass flow rate of hot fluid
Q	Rate of heat transfer
$Q_{\max}$	Maximum of heat transfer rate
R	Thermal resistance
Re	Reynold number
R_{wall}	Thermal resistance
R_i	Inner fluid thermal resistance
R_o	Outer fluid thermal resistance
R_{total}	Total of thermal resistance
ΔT	Temperature difference
$T_{c,in}$	Inlet temperature of cold fluid
$T_{c,out}$	Outlet temperature of cold fluid
$T_{h,in}$	Inlet temperature of hot fluid
$T_{h,out}$	Outlet temperature of hot fluid
ΔT_{lm}	Log mean temperature difference
U	Overall heat transfer coefficient
U_i	Overall heat transfer coefficient of inside tube
U_o	Overall heat transfer coefficient of outside tube
$\dot{v}$	Volume flow rate
V	Velocity

LIST OF ABBREVIATIONS

LMTD	Log Mean Temperature Difference
TEMA	The Tubular Exchanger Manufacturers Association

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

The heat exchanger is a device which transferred the heat from hot medium to cold medium without mixed both of medium since both mediums are separated with a solid wall generally. There are many types of heat exchanger that used based on the application. For example, double pipe heat exchanger is used in chemical process like condensing the vapor to the liquid. When to construct this type of heat exchanger, the size of material that want to uses must be considered since it affected the overall heat transfer coefficient. For this type of heat exchanger, the outlet temperature for both hot and cold fluids that produced is estimated by using the best design of this type of heat exchanger.

1.2 PROBLEM STATEMENT

The double pipe heat exchanger is used in industry such as condenser for chemical process and cooling fluid process. This double pipe heat exchanger is designed in a large size for large application in industry. For this research, the small heat exchanger of double pipe type is constructed which wants to make it practicality in daily life such in cooling the hot air from engine bay into intake manifold of car. To make this small double pipe heat exchanger type become practicality, the best design for this small double pipe heat exchanger is choose.

1.3 OBJECTIVES OF RESEARCH

The objectives of this research are as follows:

i. To study about heat transfer analysis in heat exchanger.
ii. To design the heat exchanger based on TEMA specification.

1.4 SCOPES OF RESEARCH

The scopes of this research are as follows:

i. Study on heat transfer for heat exchanger specific to double pipe heat exchanger types.
ii. Construct and simulate calculator for double pipe heat exchanger by using Visual Basic 6.0.
iii. Design the double pipe heat exchanger by using Solidwork.
iv. Fabricated the double pipe heat exchanger by using sawing, flame-cutting, oxy-acetylene welding and drilling process.
v. Analysis the heat exchanger specific to flow rate of hot and cold fluid.

1.5 SIGNIFICANCE OF RESEARCH

The significances of this research are as follows:

i. To determine the best design for double pipe heat exchanger type.
ii. To fabricate the double pipe heat exchanger.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter discussed about definition of heat exchanger, functions of heat exchanger, applications of heat exchanger, criteria for heat exchanger selection, fluid fundamental in heat exchanger, type of heat exchanger, construction of double pipe heat exchanger, flow arrangement in heat exchanger, overall heat transfer coefficient of double pipe heat exchanger, log mean temperature difference (LMTD) method for double pipe heat exchanger, effectiveness-ntu method for double pipe heat exchanger

2.2 DEFINITION OF HEAT EXCHANGER

Heat exchanger is a device, such as an automobile radiator, used to transfer heat from a fluid on one side of a barrier to a fluid on the other side without bringing the fluid into direct contact (Fogiel, 1999). Usually, this barrier is made from metal which has good thermal conductivity in order to transfer heat effectively from one fluid to another fluid. Besides that, heat exchanger can be defined as any of several devices that transfer heat from a hot to a cold fluid. In engineering practical, generally, the hot fluid is needed to cool by the cold fluid. For example, the hot vapor is needed to be cool by water in condenser practical. Moreover, heat exchanger is defined as a device used to exchange heat from one medium to another often through metal walls, usually to extract heat from a medium flowing between two surfaces. In automotive practice, radiator is used as heat exchanger to cool hot water from engine by air surrounding same like intercooler which used as heat exchanger to cool hot air for engine intake manifold by

air surrounding. Usually, this device is made from aluminum since it is lightweight and good thermal conductivity.

2.3 FUNCTION OF HEAT EXCHANGER

Heat exchanger is a special equipment type because when heat exchanger is directly fired by a combustion process, it becomes furnace, boiler, heater, tube-still heater and engine. Vice versa, when heat exchanger make a change in phase in one of flowing fluid such as condensation of steam to water, it becomes a chiller, evaporator, sublimator, distillation-coloumn reboiler, still, condenser or cooler-condenser. Heat exchanger may be designed for chemical reactions or energy-generation processes which become an integral part of reaction system such as a nuclear reactor, catalytic reactor or polymer (Fogiel, 1999). Normally, heat exchanger is used only for the transfer and useful elimination or recovery of heat without changed in phase. The fluids on either side of the barrier usually liquids but they can be gasses such as steam, air and hydrocarbon vapour or can be liquid metals such as sodium or mercury. In some application, heat exchanger fluids may used fused salts.

2.4 WHERE CAN FIND HEAT EXCHANGER

2.4.1 VEHICLE

Generally, the vehicle such as car and lorry is used petrol or diesel internal combustion engine where generated high heat and temperature which can affect durability of engine in long term and long journey. Moreover, the metal part of engine such as the crank shaft is quickly overheated and then, makes its life more short. This problem can be overcome by cooling this engine using radiator as a heat exchanger. From Figure 2.1, the hot coolant such as water which comes from the internal combustion of engine is pumped to radiator by water pump. The air from surrounding is exchanged the heat between the hot coolant at the radiator. Then, the hot coolant become cold and entered again to engine. Furthermore, other heat exchanger where used in vehicle is intercooler which designed for force induction engine such as turbocharged engine as shown in Figure 2.2. The hot air from the turbocharger is flowed through the

tubes inside the intercooler where the air from surrounding passed through this tubes and fins in the intercooler. At this time, heat is transferred from the tubes and fins to the cool surrounding air which produced cold air in the tubes. Then, this cold air is entered to the air intake of the engine. Based on theory, the cold air is denser and more molecules were carried. As a result, the performance of car is increased.

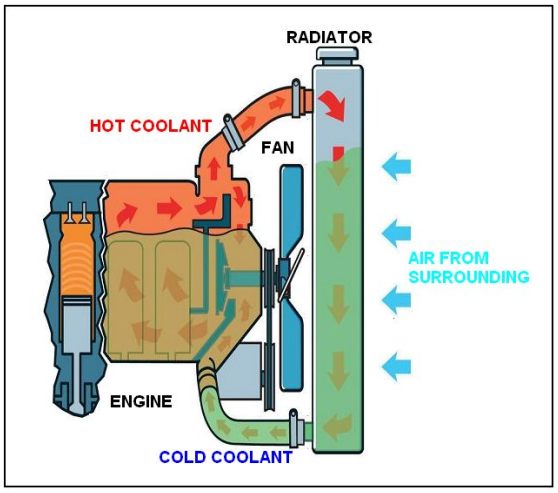

Figure 2.1: Radiator

Source: Walker (1982)

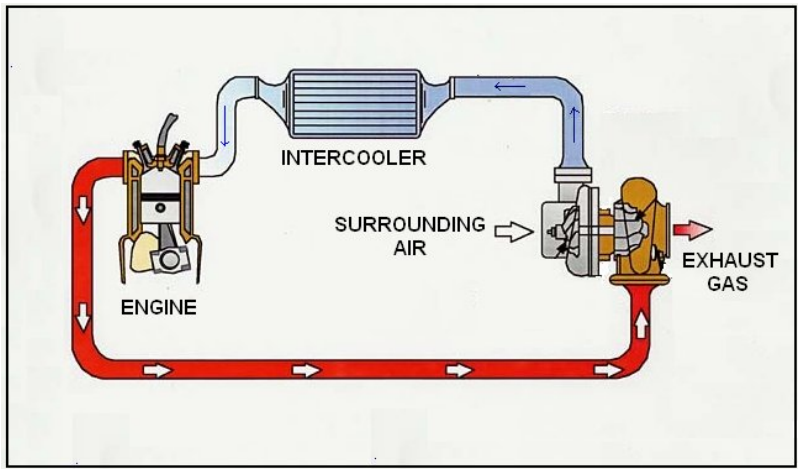

Figure 2.2: Turbocharger engine

Source: Walker (1982)

2.4.2 LABORATORY

Condenser is a device used to cool a vapor to cause it to condense to a liquid. The laboratory condenser has a straight tube which insulated with glass jacket. From Figure 2.3, the hot vapor produced by chemical reaction passes over the tube where thermometer recorded the point vapor temperature. Then, the vapor is flowed in condenser which cooled by cold water and the vapor is condensed to liquid. From heat transfer theory, the hot vapor was transferred heat to cold fluid until the hot vapor was cooled at certain temperature and become the liquid state. Lastly, this liquid as known as distillate is collected in receiver.

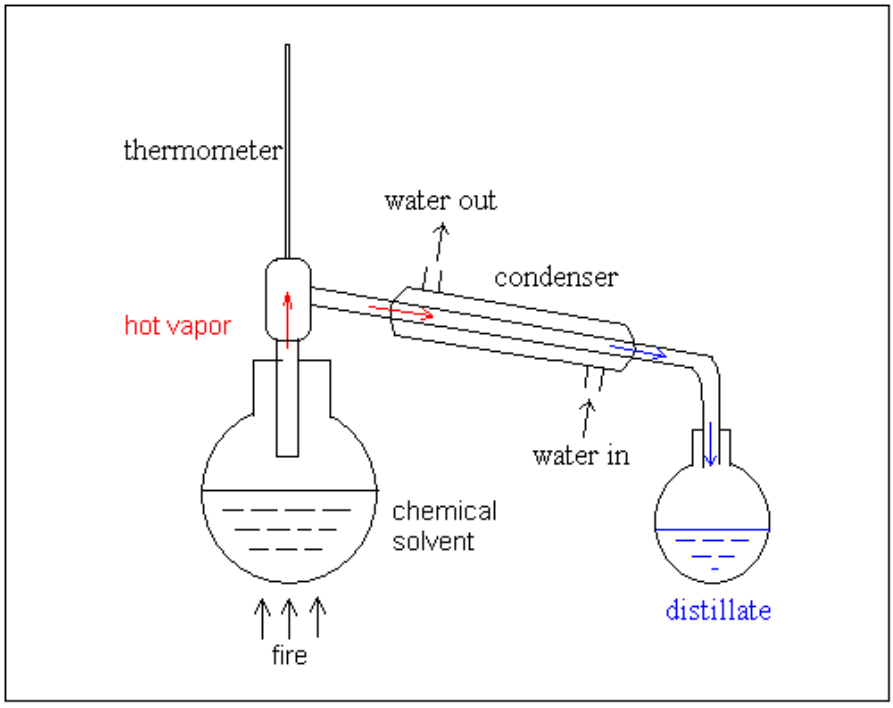

Figure 2.3: Condenser

Source: Walker (1982)

2.4.3 HOUSE

This type of water heater as shown in Figure 2.4 is difference by conventional water heater which used the water is heated in tank. For this type of water heater, it use

concept of heat exchanger where the water is instantly heated through the heat coils in the heater. The process is begin with the water entered the heater and the flow sensor is detected the water flow. Then, the computer automatically ignited the burner by using gas as a medium combustion and the burner is blow by fan. At same time, the water is circulated and heated in the heat exchanger at demand temperature. Finally, the hot water is produced.

Beside that, the heat exchanger can be found in house device such as a freezer where fish and vegetables is keep. Freezer is a device where taking the heat from inside the storage place and transferring the heat into the outside or environment. Generally, the freezer contain by compressor, condenser, drier, capillary tube and evaporator coil as shown in Figure 2.5. Firstly, the compressor pressurizes the refrigerant gas and pumped it around the system. After that, the gas is passed through the condenser coil where the heat is rejected to surrounding. Next, the gas passed through the drier to remove the dirt and enter the capillary tube which experience high pressure. Lastly, the cold gas is passed through the evaporator coil where the pressure is dropped and the gas is conducted the heat from storage place which make this place more cooled. This process of freezer system is repeated.

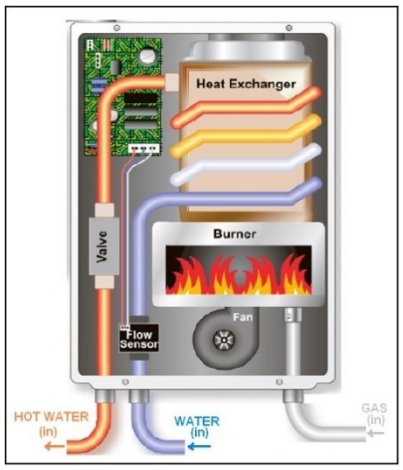

Figure 2.4: Water heater

Source: Walker (1982)